

Discover Earth



National Aeronautics and Space Administration
Earth Science Enterprise

Ozone
classroom materials for precollege teachers

Discover Earth

Classroom Materials*

- 1 Discover Earth is a NASA-sponsored project for teachers of grades 5-12, designed to:
 - enhance understanding of the Earth as an integrated system
 - enhance the interdisciplinary approach to science instruction, and
 - provide classroom materials that focus on those goals.

- 2 Discover Earth is conducted by the Institute for Global Environmental Strategies in collaboration with Dr. Eric Barron, Director, Earth System Science Center, The Pennsylvania State University; and Dr. Robert Hudson, Chair, the Department of Meteorology, University of Maryland at College Park.

- 3 The enclosed materials:
 - represent only part of the Discover Earth materials,
 - were developed by classroom teachers who are participating in the Discover Earth project,
 - utilize an investigative approach and on-line data, and
 - can be effectively adjusted to classrooms with greater/without technology access.

- 4 The Discover Earth classroom materials focus on the Earth system and key issues of global climate change including topics such as the greenhouse effect, clouds and Earth's radiation balance, surface hydrology and land cover, and volcanoes and climate change. All the materials developed to date are available on line at < <http://www.strategies.org> >

- 5 You are encouraged to submit comments and recommendations about these materials to the Discover Earth project manager, contact information is listed below. You are welcome to duplicate all these materials.

Colleen Steele, Discover Earth Project Manager
Institute for Global Environmental Strategies
2111 Wilson Boulevard, Suite 700
Arlington, Virginia 22201
v (703) 875-8634 f (703) 875-8635
colleen_steele@strategies.org

* These materials were developed under NASA Grant NAG5-3889

Ozone: The Earth's Security Blanket



-
- Authors:** Roxanne Hosking, Eastern Connecticut State University,
Willimantic, CT
Gail Shears, Pittsford Middle School, Pittsford, NY
- Grade Level:** Upper elementary, suggested grades 5-6
- Objectives:** The student will demonstrate knowledge of:
- what ozone is,
 - where ozone is found,
 - why it is important to understand ozone,
 - what role humans play in ozone production and depletion,
 - how changes in ozone levels affect us; and
 - managing basic ozone statistical data.
- Disciplines:** Earth science
health (environmental impact on lifestyle)
mathematics (unit measurements and graphs)
social studies (current events and history)
technology
- Key Concepts:** atom
"good" and "bad" ozone
molecule
ozone
ozone hole
stratosphere
troposphere
ultraviolet radiation
- Enrichment terms:** Dobson unit
melanoma
necrosis
- Cognitive Tasks:**
- The students will demonstrate numerous cooperative learning strategies in response to a presentation of basic concepts. These will be implemented by use of transparencies, videos, lithographs, posters, charts, graphs, Internet access, and publications.
 - Ozone will be classified by tropospheric and stratospheric levels.
 - Students will interpret data regarding ozone levels.
- Time Requirements:** five to eight 40-minute lessons
- Data Sources:** See list at end of lesson

Prerequisite**Skills:**

Internet access
Knowledge of atoms and molecules
Knowledge of graphs

Materials:

Ozone: What is it, and why do we care about it? NASA Facts, NF-198
Transparencies: 1-9 through 1-21; 2-12 and 2-13 optional

Black light demonstration, lesson 4

- Black light source
- Luminous paint (green or orange will show up well)
- Map of any geographical region (preferably a region you are familiar with such as the US)
- Plastic. Approximately one square yard of translucent or transparent plastic-- either a rigid sheet of plastic, or a non-rigid piece of plastic attached to a frame may be used. If using non-rigid plastic, the frame may be as simple as cutting a frame out of poster board. Examples of non-rigid plastic are a shower-curtain liner or paint drop cloth. Translucent plastic will provide greater contrast than will transparent, and consequently more understandable results. Cut a one-inch hole in the center of the plastic.

**Background
for Teachers:**

“Common Questions about Ozone,” NOAA, 1994
“Ozone Depletion: The Facts Behind the Phaseout,” EPA 3-95

Assessment:

rubric on page 1-8

**Data Sources &
Supplemental
Materials:**

page 1-6 and 1-7

Procedure:

The following series of lessons focus on cooperative learning. The skills to be mastered are specific and measurable, while allowing latitude for a variety of academic abilities and learning styles.

The lesson plans are media rich. Although the listed resources are excessive for any one lesson, they provide a variety of choices that should be responsive to almost any situation and need. Transparencies can be made from enclosed pages 1-9 through 1-21, and are designed to stimulate discussion and group work.

Recognition and appreciation are extended to Pittsford Central Schools of Pittsford, New York for the *Middle School Problem Solving Rubric*, page 1-8.

Lesson 1

- Introduction, transparency 1-9, *Ozone - The Earth's security blanket*
Class discussion on what this means
- Transparency 1-10, *Ozone definition*
Also review definitions of atom and molecule
- Transparency 1-11, *Is ozone good or bad?*
Class cooperative discussion groups; share with the class
- Transparency 1-12, *Earth's atmosphere: a thin shell*
Introduce layers of the atmosphere, with emphasis on troposphere and stratosphere
- Assign informal home survey on knowledge and opinions of ozone, along with any current events
- Supplemental Media (see, **Data Sources and Supplemental Materials**):
Ozone/Goddard Space Flight Center/Nimbus-7 Total Ozone Mapping Spectrometer poster
history chart of ozone on back of poster

Lesson 2

- Review *Earth's atmosphere: a thin shell*, 1-12
- Survey students for home questions and current events
- Transparency 1-13, definition of *stratospheric ozone*
- Transparency 1-14, definition of *tropospheric ozone*
Compare with stratospheric ozone and discuss
- Repeat transparency 1-11, *Is ozone good or bad?*
cooperative discussion groups
- Video - incorporate choice of films relevant to the instructional group, if possible
- Supplemental Media:
Transparency 1-15, *Atmospheric model* which shows layers of the Earth's atmosphere

Lesson 3

- Transparency 1-16, *Why is it important to understand ozone?*
cooperative discussion groups predict value of ozone knowledge
- Transparency 1-17, *Ozone in the troposphere: bad for breathing*
Research and discussion of tropospheric ozone (ground level), the primary component of photochemical smog
- Video "Sunsplash"
- Supplemental Media (see, **Data Sources and Supplemental Materials**):
Earth's Changing Atmosphere poster
Global Sea Surface Temperature lithograph
Ozone highlights, 1-18
World Cloud Cover lithograph

Lesson 4

- Review tropospheric ozone briefly
- Transparency 1-19, *Ozone in the stratosphere: putting on the sunscreen*
Additional transparencies
- Discuss ozone hole - transparency 1-18, *Ozone highlights*; 2-12, *Adaptation strategies*; and 2-13, *Mitigation Strategies* can be used to discuss the ozone hole, and responses; use Ozone/Goddard Space Flight Center/Nimbus-7 Total Ozone Mapping Spectrometer poster (see **Data Sources and Supplemental Materials**)
- Black light demonstration procedure (see **Materials**)
 1. Mount the map on a wall.
 2. Use the luminous paint to outline the political boundaries, major cities, and other geological landmarks.
 3. Have two students hold the plastic sheet about one foot in front of the map. Another student will shine the black light on the plastic and map.
 4. Move the plastic (and consequently the hole) around in front of the map and observe the glow on the map. This indicates how the thinning or depletion of the ozone layer in the atmosphere--the ozone hole--allows ultraviolet rays to reach the surface of Earth.
 5. Discuss the following.
 - ◇ How does the size of the ozone hole affect the size of the geographical area affected? Enlarge the hole and repeat the black light demonstration to determine.
 - ◇ Does the ozone hole move around the Earth? How could you find out?
 - ◇ Does the ozone hole appear above specific areas of Earth, or is this a random occurrence?
 - ◇ What could be done to replenish the "missing" ozone?
- Enrichment - lesson on Dobson Units,
Transparency 1-20, *Measurement of stratospheric ozone*
- Supplemental Media
Antarctic Ozone Hole, NASA Lithographs HqL-366, HqL-371
Transparency 1-21, *Ozone destruction -- a catalytic process*

Lesson 5

- Review good and bad ozone, troposphere and stratosphere, ozone hole
- Netscape - access NASA on the Internet
- Supplemental Media:
See Web Sites under **Data Sources and Supplemental Materials**

Lesson 6

Teams of 2-4 students will develop a poster, model, mural, project, etc. on ozone using at least three sources. According to the rubric for problem-solving, each team will create a one page explanation of the ozone-related topic they have chosen. Evaluation will be based on problem statement, hypothesis, materials, procedure, data, conclusion, and evaluation on the science standards matrix.

- Assessment
 - Discuss the expectations on the problem-solving assignment and relative expectations on the evaluation rubric
- Establish parameters and time frame

Data Sources and Supplemental Materials

All the lithographs, posters and videos listed in this section are NASA products. To obtain NASA materials, contact your regional NASA Teacher Resource Center (list enclosed).

Lithographs:

- Apollo 17 View From Earth: HqL-363
- Global Sea Surface Temperature: HqL-324
- McCandless Flies First "Solo" in Space: HqL-353
- Nimbus-7 TOMS Images: The Eight Marches: HqL-366
- TOMS Ozone - Difference from Climatology: HqL-371
- Total Ozone Mapping Spectrometer/Earth Probe (TOMS/EP-94): HqL-397
- World Cloud Cover Pattern: HqL-326

Posters:

- Earth's Changing Atmosphere, Investigating its Mysteries: WED 114/9-94
- Ozone/Goddard Space Flight Center/Nimbus-7 Total Ozone Mapping Spectrometer: WAL-144/1-94

Publications:

- "A for Atmospheric Trace Gases," CDIAC Communications, Carbon Dioxide Information Analysis Center World Data Center, Oak Ridge National Laboratory, Spring 1996 Issue No. 22, Carbon Dioxide Information Analysis Center, PO Box 2008, Oak Ridge, TN 37831-6335; (615) 574-3645 (CDIAC User Services)
- "Common Questions About Ozone," reprinted from Scientific Assessment of Ozone Depletion: 1994, World Meteorological Organization (Global Ozone Research and Monitoring Project - Report NO.37), NOAA, NASA, UNEP, WMO. World Meteorological Organization, Global Ozone Observing System, PO Box 2300, 1211-Geneva-2, Switzerland
- Earth Observing System (EOS) Glossary and list of Acronyms/Abbreviations, NASA Goddard Space Flight Center, July 1992
- EPA Ozone Depletion: The Facts Behind the Phaseout, United States Environmental Protection Agency, Air and Radiation Stratospheric Protection Division, 6205J, March 1995, 430-F-95-055, (202) 775-6677
- EPA: Auto Air Conditioners and the Ozone Layer: A Consumer Guide, United States Environmental Protection Agency, Office of Air and Radiation (6205 J), EPA 430-F-94-009, May 1994, (800) 296-1996, Monday-Friday, 10:00 a.m. to 4:00 p.m.
- EPA: Health Effects of Overexposure to the Sun, United States Environmental Protection Agency, Air and Radiation (6205 J), EPA 430-F-95-003, January 1995, (800) 296-1996, Monday-Friday, 10:00 a.m. to 4:00 p.m.
- EPA: Protecting the Ozone Layer: A Check List for Citizen Action, United States Environmental Protection Agency, Office of Air and Radiation (6205 J), EPA 430-F-94-007, April 1994, (800) 296-1996, Monday-Friday, 10:00 a.m. to 4:00 p.m.
- Levine, Joel S., "Ozone, Climate, and Global Atmospheric Change," Office of Global Programs. Reprinted from Science Activities, Volume 29, Number 1, Spring 1992, pp 10-16, Heldref Publications, Washington, DC
- Looking At Earth From Space, Glossary of Terms, EP-302, Mission To Planet Earth, NASA, August 1994
- MacKenzie, James J. and Mohamed T. El-Ashry, Air Pollution's Toll on Forests and Crops, Yale University Press, 1990, pp 8-15 and 297-300 are most helpful
- NASA Earth View, mruzek@usra.edu

- Ozone: What is it, and why do we care about it? NASA Facts - NF-198, Mission to Planet Earth, NASA Goddard Space Flight Center, December 1993
- TRENDS A report available from the Carbon Dioxide Information Analysis Center, PO Box 2008, Oak Ridge, TN 37831-6335; (615) 574-3645 (CDIAC User Services), at no cost.
- Understanding Our Changing Planet: NASA's Mission to Planet Earth, 1995 Catalog of Education Programs and Resources, EP-335, NASA Educational Services K-University, 1995
- Understanding Our Changing Planet: NASA's Mission To Planet Earth, 1995 Fact Book, NASA Goddard Space Flight Center, 1995
- Wayne, Richard P., Chemistry of Atmospheres, Claredon Press, Oxford, 1991, pp 161-191 are most helpful

Videos:

Note: These videos are not available through NASA CORE, contact your NASA ERC. Length of videos indicated in minutes and seconds.

NASA "Beyond the Clouds: The Upper Atmosphere" 12:10/NASA

NASA "Evolution of the Ozone Hole as seen by TOMS" 10:00/NASA

NASA "Global Change Dynamics" 7:35/JPL

NASA "Sunsplash" 7:53/NASA

Internet Addresses:

Consortium for International Earth Science Information Network: <http://www.ciesin.org>
- particularly <http://sedac.ciesin.org/ozone/>

Earth Observing System Educator's Visual Materials:
http://spso.gfsc.nasa.gov/eos_edu.pack/toc.html

Earth Observing System Project Science Office:
http://spso.gsfc.nasa.gov/spso_homepage.html

NASA Spacelink: <http://spacelink.msfc.nasa.gov>

NOAA Climate Prediction Center: <http://cops.wwb.noaa.gov/>

U.S. Environmental Protection Agency (EPA): <http://www.epa.gov>

U.S. Global Change Research Information Office: <http://www.gcrio.org/>

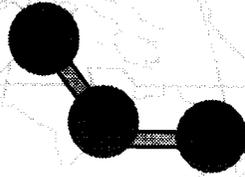
Middle School Problem Solving Rubric

Standard Criteria	Excellent 4	Good 3	Fair 2	Poor 1
I. Problem	The problem is stated clearly and objectively as a question. It is sufficiently limited in scope.	The problem is stated clearly and objectively as a question, but it is too broad in scope.	The problem is stated in the form of a question but is either not stated objectively or it is too broad in scope.	The problem is not stated clearly and/or objectively. It is not in the form of a question.
II. Key Cause	A prediction is made in a complete sentence. One variable is directly related to the problem.	A prediction is made but it is too vague.	The key cause is not given as a complete sentence.	The key cause did not relate to the problem.
III. Method	A plan is presented for a controlled experiment. All steps are included, in order, with enough detail and are in complete sentences. A colored, detailed, labeled story board of 2-6 frames is included.	A plan is given that needs modification. The overall approach to the problem is understood but there are some missing steps or details. Story board is missing some details.	A satisfactory plan is presented but it needs more detail. Some steps are missing or out of order. Not all steps are in complete sentences. Story board is missing some details.	A poor procedure is present. The steps are missing or lack detail. Steps are not written in sentences. No story board is given.
IV. Materials	All the materials needed for the experiment are accurately listed.	All the materials needed for the experiment are listed but not accurately described.	The list of materials is missing some items.	The list of materials is not given.
V. Data	Data charts, tables & diagrams (pictures) are included in appropriate, detailed, neat form. Graphs are in good form, neat, and correctly plotted, titled and labeled.	Charts, tables & diagrams (pictures) are included but lack some details. Graphs are basically good but have labeling or plotting mistakes or missing title.	Charts, tables & diagrams (pictures) are incomplete and/or in poor form. Graphs are included but are poorly labeled, messy or incorrectly plotted or titled.	Appropriate charts, tables & diagrams (pictures) are missing. Graphs are omitted.
VI. Conclusion	Data results are expressed & some patterns are indicated in a general, well written summary statement. It is correctly indicated as to whether the data supported or refuted a key cause.	Data results are expressed & some patterns are indicated in a general summary statement. Sentence structure needs to be better. It is correctly indicated that the data supported or refuted the key cause; however, some further explanation is needed.	Data results are expressed but no patterns are indicated. Data is too specific, not general enough for a summary. It is indicated incorrectly that the data supported or refuted the key cause.	Data results and patterns are not expressed in a well written, general summary format. It is not indicated whether or not the data supported or refuted the key cause.
VII. Evaluation	A thorough evaluation is presented in a well written format. All errors are documented & nothing is mistakenly listed as an error.	A fairly complete evaluation is presented in a well written format. Some things listed as errors are not. Sentences may not be complete.	An incomplete evaluation is presented. The evaluation is not written in complete sentences.	There is no written evaluation of the procedure.
Overall Appearance	The overall appearance is excellent. The entire write-up is neat and orderly. Extra effort is shown in designing and completing the charts, graphs, pictures, and diagrams. Parts of the lab are in the right order.	The overall appearance is good. Most of the write-up is neat & orderly. Color is used on diagrams.	The overall appearance is satisfactory. Some of the write-up is messy. Color is missing. Sections of the lab are in the wrong order.	Poor overall appearance.



ozone

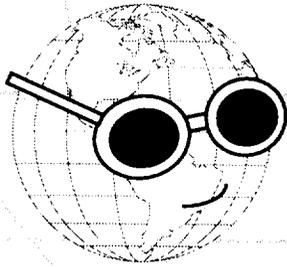
Earth's security blanket



**Ozone is a molecule
made up of three
atoms of oxygen**

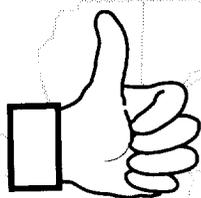
and

**serves as the Earth's
sunscreen, or
protective
blanket.**



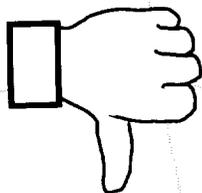


Is ozone



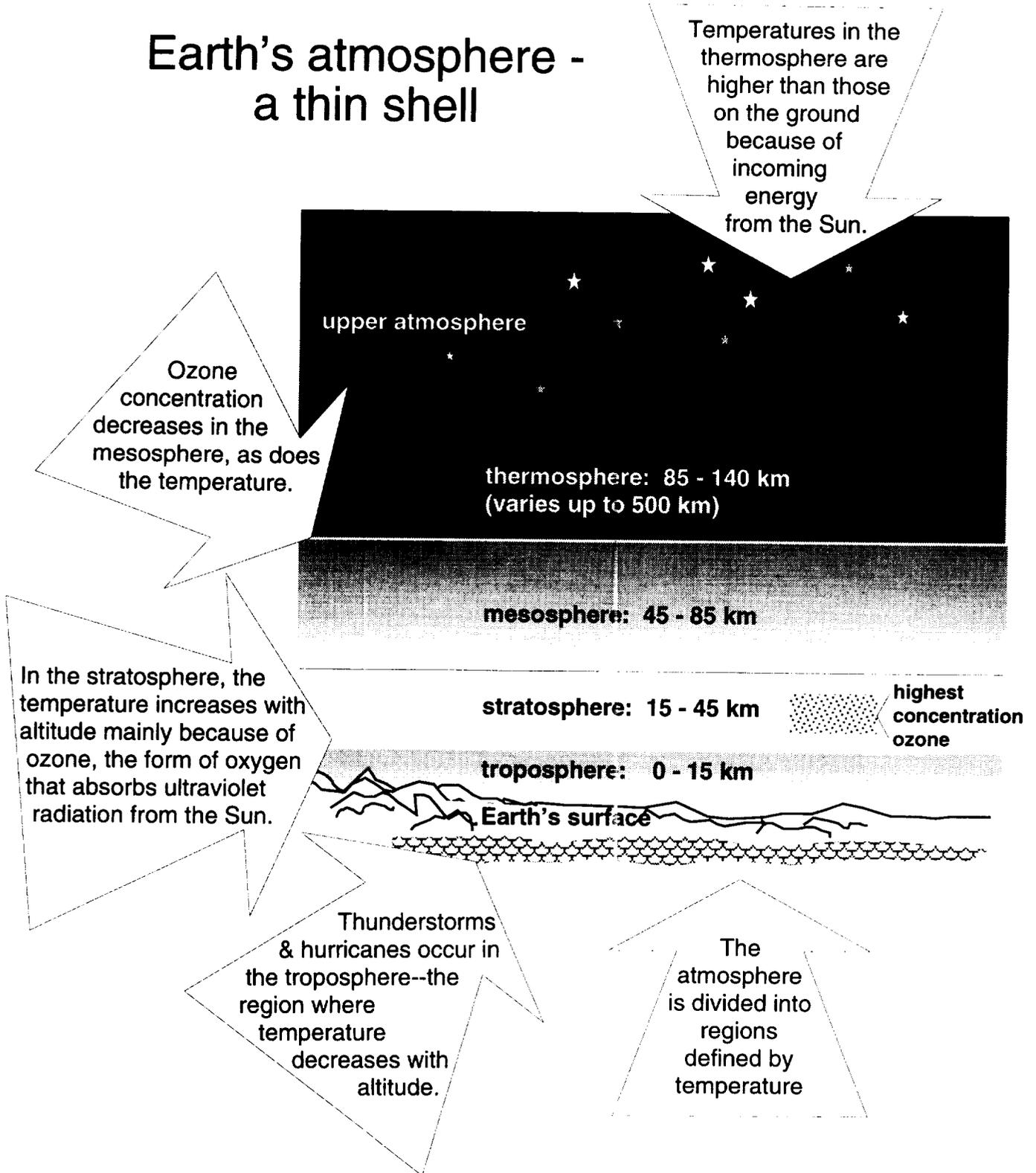
good

or

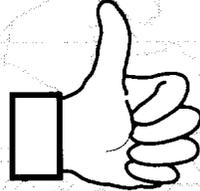


bad?

Earth's atmosphere - a thin shell



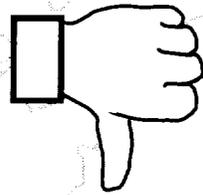
stratospheric ozone



Ozone in the stratosphere occurs naturally, and provides a protective layer shielding the Earth

- 1) from ultraviolet radiation and
- 2) potentially harmful health effects on humans and the environment.

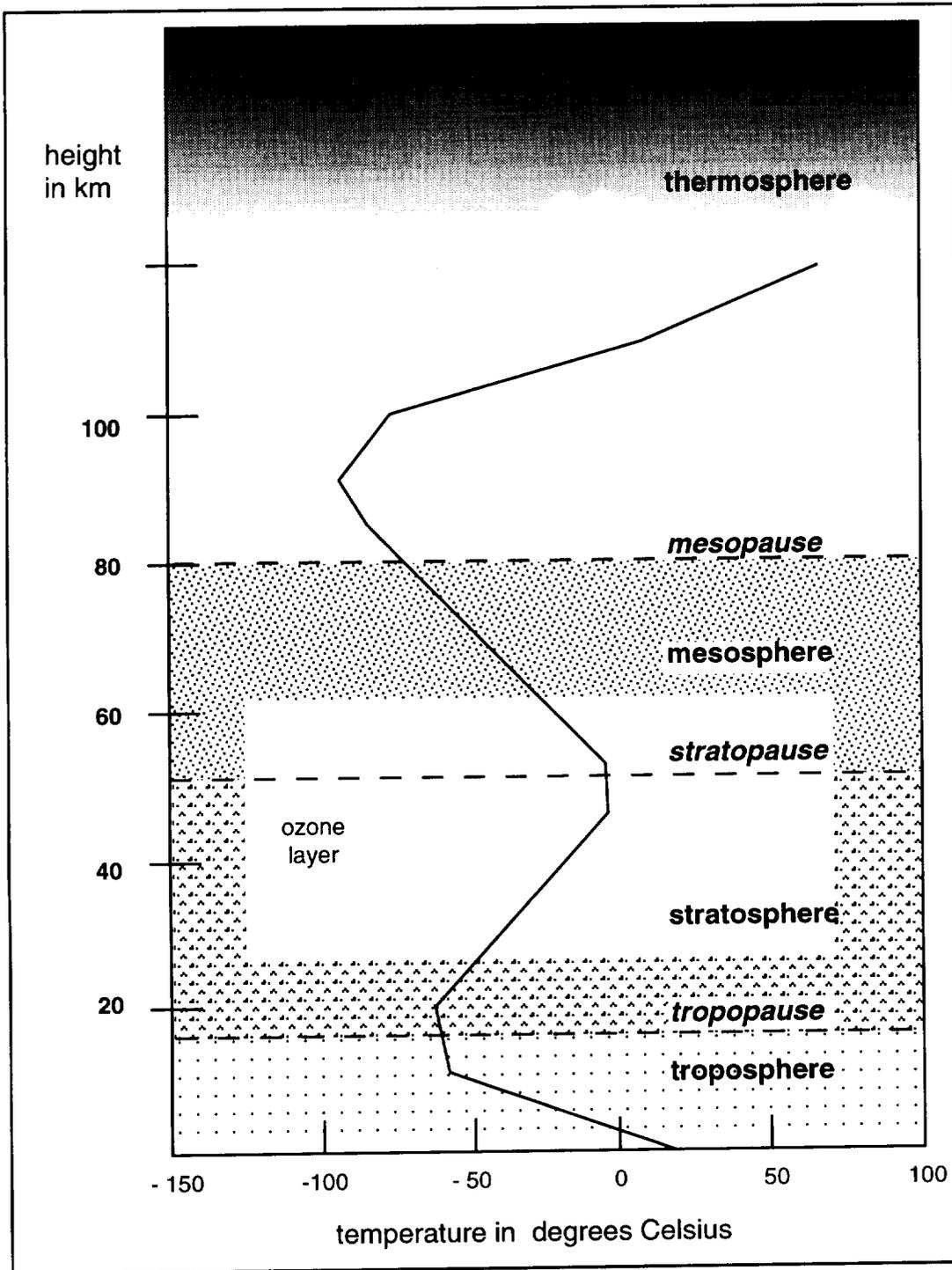
tropospheric ozone



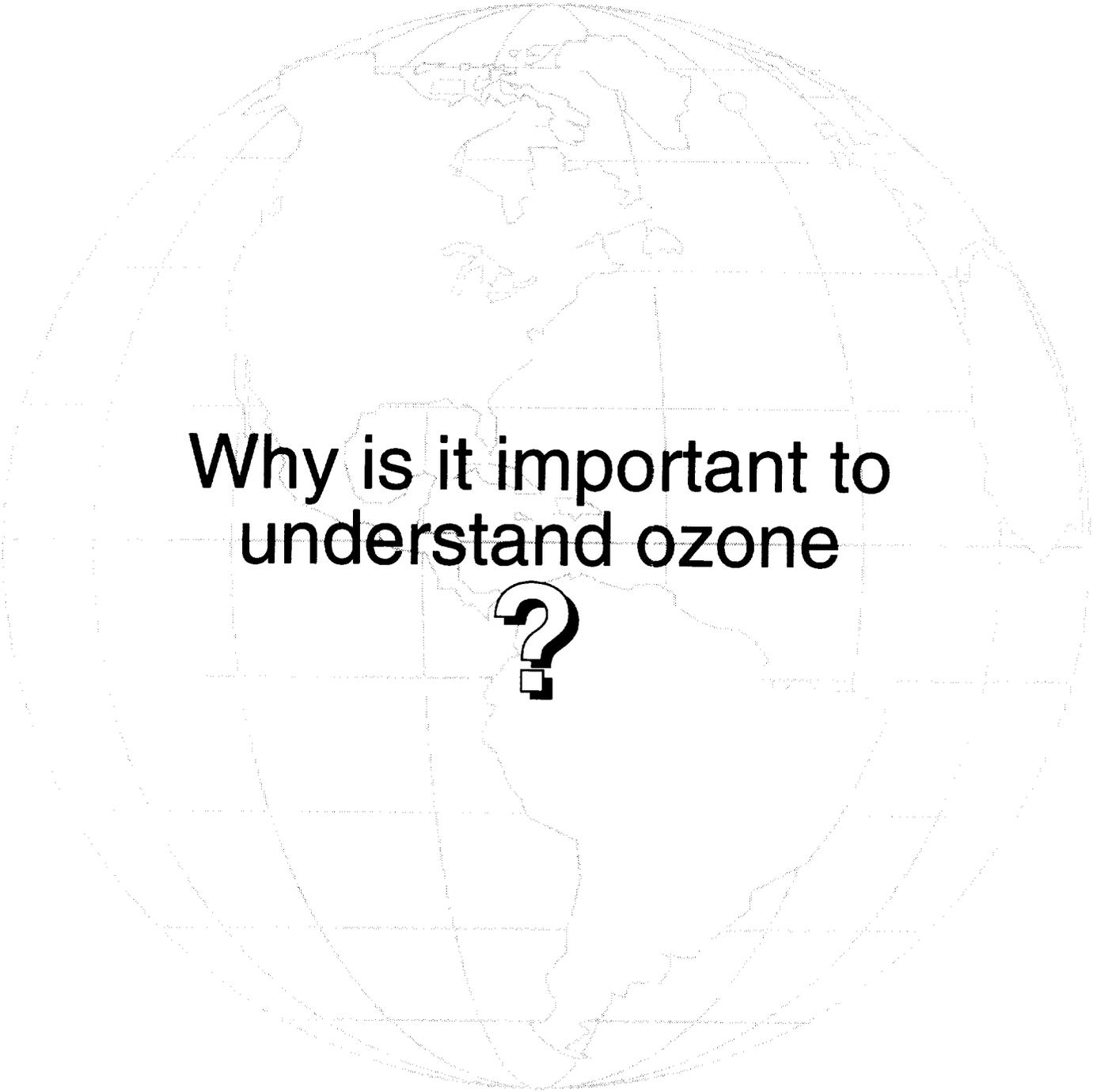
Ozone in the troposphere is a chemical oxidant, or a new, changed form of the original.

It is a major part of smog and greenhouse gases created by humans.

Atmospheric Model



average air temperature at various altitudes/layers of the atmosphere

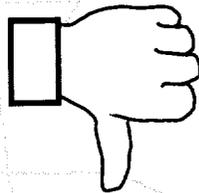


**Why is it important to
understand ozone**

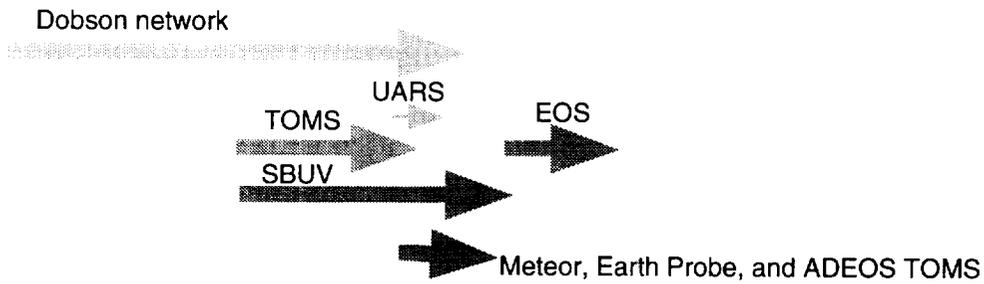
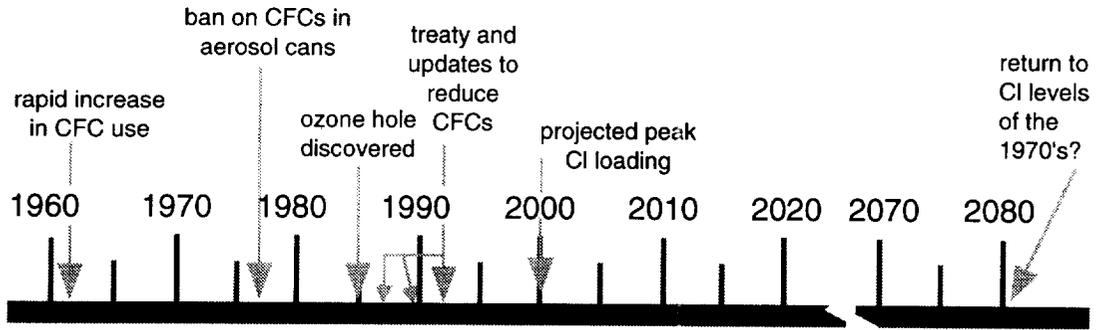




**Ozone in the troposphere:
bad for breathing.**



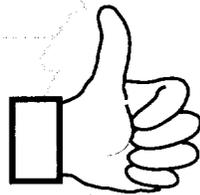
Ozone Highlights



ADEOS	Advanced Earth Observing System
EOS	Earth Observing System
SBUV	Solar Backscatter Ultraviolet (radiometer)
TOMS	Total Ozone Mapping Spectrometer
UARS	Upper Atmosphere Research Satellite

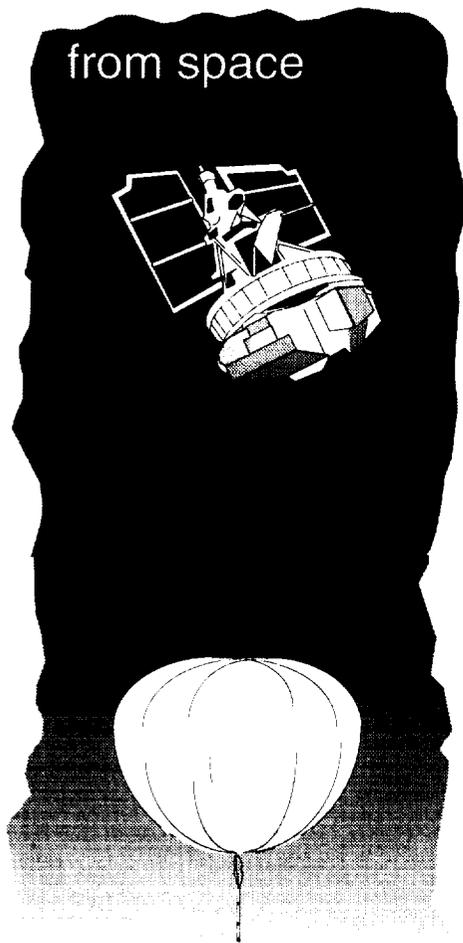


**Ozone in the stratosphere:
putting on the sunscreen.**



Measurement of Stratospheric Ozone

from space



Measurements from NASA* and NOAA** satellites began in late 1960's and continue today.

Amount and distribution of ozone molecules in stratosphere varies greatly over the globe, changing in response to natural cycles such as seasons, sun cycles, and winds.

Satellite measurements provide simultaneous information about ozone levels over the entire Earth, and continuous information over a long period of time.

Instruments carried on balloons and aircraft flying at altitudes above 10 miles make it possible to measure ozone *in situ* (in place--where it occurs in the atmosphere).

NASA ER-2 aircraft carry instruments that measure many components of the complex chain of chemical events that control ozone loss.

from the ground



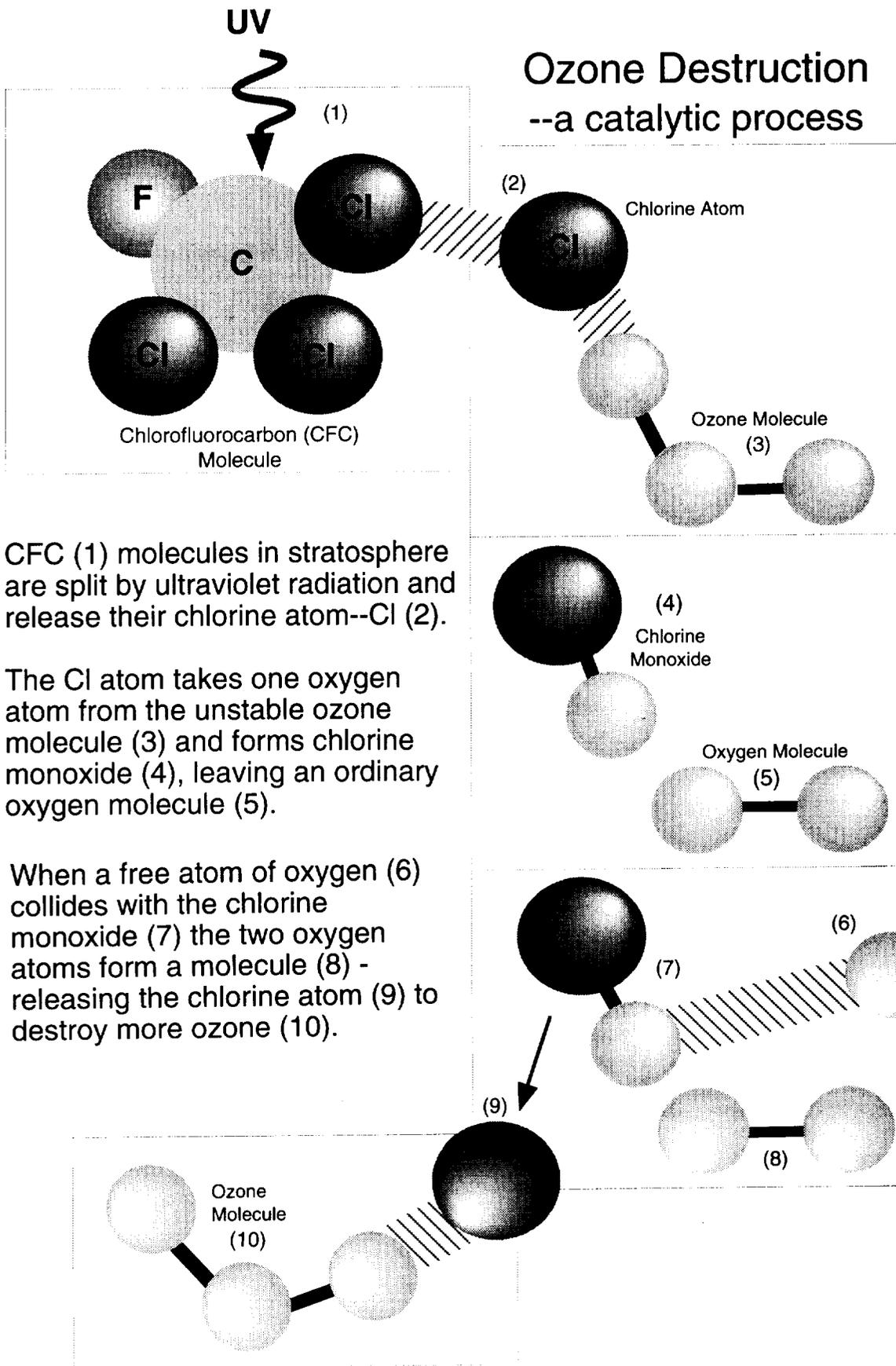
Instruments on the ground are also used to measure ozone. Dobson units (named for researcher, G. Dobson) are the standard way to express the total amount of ozone in a vertical column of the atmosphere (from the ground to the top of the atmosphere).

Dobson measurements were begun in the 1920's. A world-wide network of regular ozone monitoring has continued since 1957.

* National Aeronautics and Space Administration

** National Oceanic and Atmospheric Administration

Ozone Destruction --a catalytic process



CFC (1) molecules in stratosphere are split by ultraviolet radiation and release their chlorine atom--Cl (2).

The Cl atom takes one oxygen atom from the unstable ozone molecule (3) and forms chlorine monoxide (4), leaving an ordinary oxygen molecule (5).

When a free atom of oxygen (6) collides with the chlorine monoxide (7) the two oxygen atoms form a molecule (8) - releasing the chlorine atom (9) to destroy more ozone (10).

The Ozone Problems: Stratospheric and Tropospheric



- Authors:** Cecilia M. Fernandez, Gonzaga College High School, Washington, DC
Keith McKain, Milford Senior High School, Milford, DE
Richard Taylan, F.D. Roosevelt High School, Hyde Park, NY
- Grade Level:** high school
- Objectives:**
1. To be familiar with the properties of ozone.
 2. To understand the difference between “good” and “bad” ozone.
 - the importance of ozone in the stratosphere.
 - the consequences of high ozone levels in the troposphere.
 3. To understand the processes that regulate ozone levels in the stratosphere.
 - the concept of ozone depletion.
 - the relationship between CFC’s and ozone.
 4. To understand how ozone is produced in the troposphere.
 - analyze weather data and determine which two variables are most important in determining the ozone level in the troposphere.
 5. To be familiar with the techniques used to monitor ozone.
- Disciplines:** biology, chemistry, Earth science, environmental science, mathematics, social science
- Key Concepts:**
1. Ozone balance in the stratosphere
 2. Ozone depletion (the leaky bucket)
 3. Ozone level regulating processes
 4. Properties of ozone
- Cognitive Tasks:** graph and data analysis
- Time Required:** 4 class periods, 45 minutes each

Data Sources: Data for Project #1, As soon as it becomes available - it will be placed on the Internet

Day 2: source at the University of Maryland.

Data for Project #2: Weather data (page 1-27) for College Park, Maryland provided by Mr. William Ryan, Department of Meteorology, University of Maryland at College Park.

Data for your location should be available from the State Department of Environmental Control, State Climatologist or <http://www.ncdc.gov>, and a local weather station.

Prerequisites: algebra, graphing, graph analysis

Background: meteorology - the atmosphere, weather variables

Assessment: Students will produce a lab report for each project. It should include graphing of the data and a complete analysis and discussion of the results.

Classroom Materials:

1. Handouts of data tables
2. Extra: computers with Internet access and spreadsheet software

Resources: See page 1-26

Procedure:

Day One: NASA Facts-198 covers information needed to prepare the introduction.

Introduction - lecture. Alternately, groups of students could prepare and introduce various aspects (stratospheric ozone, tropospheric ozone, consequences of decrease/increase in the ozone layer, etc.) One group could make a poster or styrofoam models illustrating ozone destruction.

1. What is ozone?
2. Where is it found in the atmosphere?
3. What is the difference between "good" and "bad" ozone?
 - a) the importance of ozone in the stratosphere.
 - b) the consequences of high ozone levels in the troposphere.

4. What are the processes that regulate ozone levels in the stratosphere?
 - a) the concept of ozone depletion.
 - b) the relationship between CFC's and ozone.
5. What techniques are used to monitor ozone? (A viewgraph can be made from page 1-20).

Day Two: Project 1 -Stratospheric Ozone and Chlorine Monoxide
Students will analyze ozone and chlorine monoxide data to show any correlation between the two.
NOTE: The chlorine monoxide data is currently not available. As soon as it is, it will be placed on the Internet.

Discuss the results of Project 1.

Day Three: Project 2 - Factors affecting the levels of tropospheric ozone.
Cooperative teams of students will graph the tropospheric ozone data and compare it to weather variables (temperature, cloud cover, wind speed, relative humidity, etc.) in an urban area and analyze the graph:

- to see if any correlation is present and,
- to identify which two factors seem to be the most important in determining the ozone levels in the troposphere.

A data set is included on page 1-27. Data for your location should be available from the State Department of Environmental Control, State Climatologist or <http://www.ncdc.gov>, and a local weather station.

Day Four: Present results from Project 2

How is ozone produced in the troposphere?

1. Analyze weather data and determine which two variables are most important in determining the ozone level in the troposphere.
2. Identify conditions that affect the ozone levels.
3. Sample comparisons are shown on pages 1-28 and 1-29.

The Ozone Problems: Stratospheric and Tropospheric

Key Terms

atomic oxygen	Atom form of oxygen, very reactive, it is formed when elemental oxygen (O ₂) is irradiated with UV radiation. Very important in the formation of ozone.
chlorofluorocarbons	(CFC's) Family of compounds of chlorine, fluorine, and carbon; CFC's are entirely man made. They are used in fire extinguishers, as refrigerants, as solvents for cleaning electromagnetic microcircuits, and as propellants. CFC's contribute to the atmospheric greenhouse effect and destroy the ozone in the stratosphere.
Dobson Unit (DU)	The standard measure of ozone concentration in the atmosphere. One DU is 2.7×10^{16} ozone molecules per square centimeter. One DU refers to a layer of ozone that would be 0.001 cm thick under conditions of standard temperature (0° C) and pressure.
ozone (O ₃)	An almost colorless gaseous triatomic form of oxygen with an odor similar to weak chlorine. The highest natural concentration is found in the stratosphere and is known as stratospheric ozone. Ozone also forms in polluted air near the Earth's surface (tropospheric ozone), where it is the main ingredient of photochemical smog.
ozone depletion	Reduction in total ozone due to increased ozone loss in the stratosphere.
stratosphere	The layer of the atmosphere above the troposphere and below the mesosphere (between 10 and 50 km), generally characterized by an increase in temperature with height.
troposphere	The layer of the atmosphere extending from the Earth's surface up to the stratosphere (about 10 km above the ground).
ultraviolet radiation	Electromagnetic radiation with longer wavelength and less energy than X-ray but shorter wavelength and more energy than visible. UV radiation is the major energy source for the stratosphere and mesosphere, and plays a dominant role in Earth's energy balance. Ozone in the stratosphere absorbs nearly all the biologically damaging UV rays.

Resources:

Publications

Note: To obtain NASA materials, contact your regional NASA Education Resource Center

1. Ahrens, C. Donald, Meteorology Today - an Introduction to Weather, Climate, and the Environment. 5th Edition, West Publishing Co., St. Paul, MN 1994
2. *The Atmosphere*, Laserdisc by VIDEODISCOVERY, \$475,
<http://www.videodiscovery.com/vdyweb>
3. "Atmospheric Chemistry: Causes and Effects" Reprinted from MTS Journal, Volume 25, Number 3, pp. 12-18, Marine Technology Society, Washington, DC
4. Ennis, Christine A. and Nancy H. Marcus, Biological Consequences of Global Climate Change, Module 107, Global Change Instruction Program 1994
5. NASA Facts a) NF-198 Ozone: What Is It, and Why Do We Care About It?
b) NF-219 Total Ozone Mapping Spectrometer/Earth Probe (TOMS/EP-94)
6. NASA Lithographs: HQL-397, HQL-366, HQL-371
7. "Ozone, Climate, and Global Atmospheric Change" Reprinted from NOAA's "Global Change Education Resource Guide" Science Activities Volume 29, Number 1 Spring 1992, pp.10-16 Heldref Publications, Washington, DC
8. *Ozone, TOMS gridded data*, CD ROM NASA-Goddard, NSSDC
9. American Chemical Society, Chemistry in Context. Wm. C. Brown Publishers, Dubuque, IA, 1994 ACS

Internet Sites

stratospheric ozone
and human health

<http://sedac.ciesin.org/ozone/>

total column
ozone maps

<http://nic.fb4.noaa.gov/products/stratosphere/sbuv2to/>

TOMS home page,
ozone archives and maps

<http://jwocky.gsfc.nasa.gov>

ozone information and
links (check both
Air Quality Forecasts &
Air Quality Observations)

<http://www.meto.umd.edu/~ryan/>

Going Further:

As a long term project the students could access stratospheric ozone data from the Internet and prove the concentration of stratospheric ozone has decreased in the last 10 years.

Weather Data Table - July 1992
University of Maryland, College Park, Maryland

Date
 example 920701
 92 is year - 1992
 07 is 7th month - July
 01 is 1st day of month
 so date is July 1, 1992

Ozone*
 Peak one hour average
 ozone for any monitor in
 the Baltimore area.
 Measured in parts per
 billion by volume (ppbv).

Clouds
 0 indicates a clear sky
 10 is completely overcast

Hi-Temp
 High temperature for the
 day in Baltimore in
 degrees Fahrenheit

Wind Speed
 Surface wind speed at
 Baltimore Washington
 Airport at 2 pm,
 measured in knots.

Pre-Oz
Previous day's ozone
 Maximum one hour
 average from previous
 day--used for
 comparison.

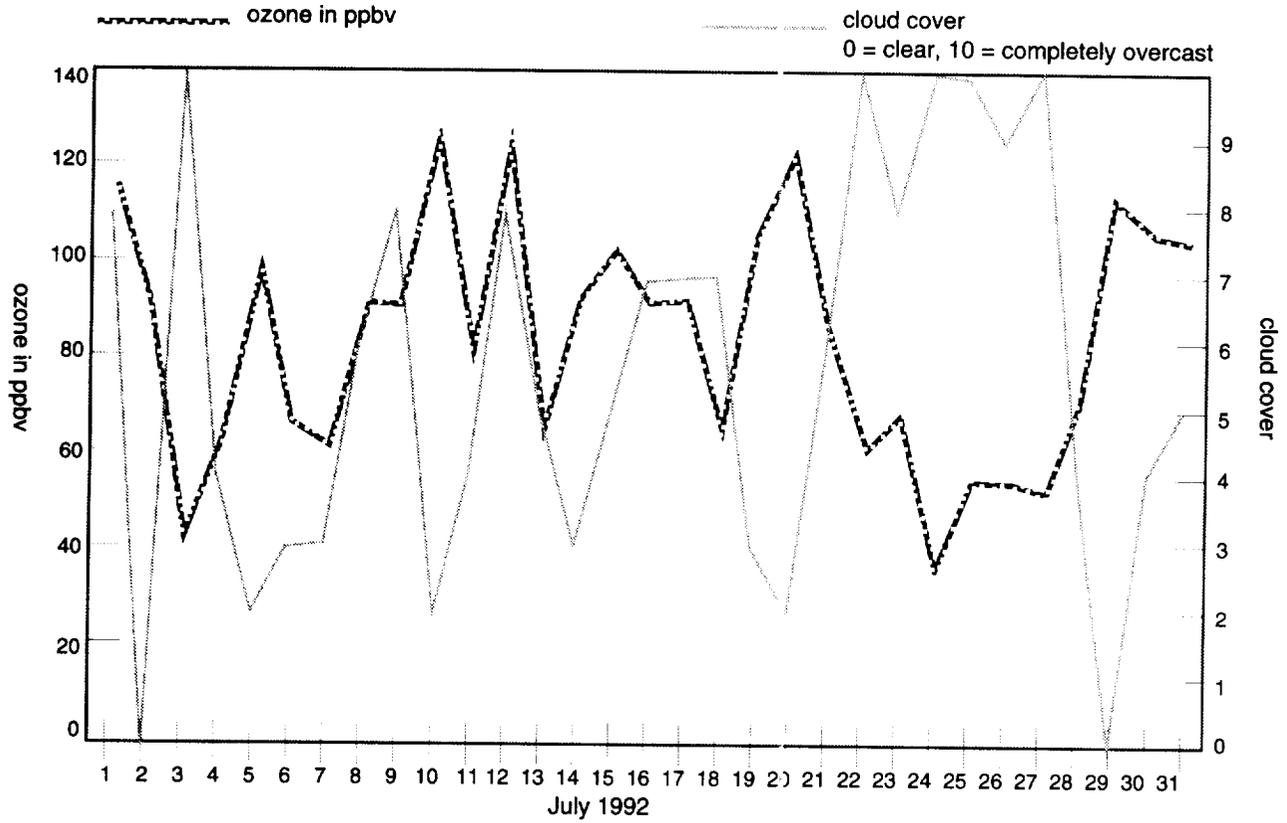
RH Relative humidity
 Amount of water vapor in
 the air relative to the
 amount required for
 saturation, expressed as
 a percentage.

Date	Ozone	Clouds	Hi-Temp	Wind Spd	Pre-Oz	RH
920701	116	8	89	8	112	59
920702	93	0	81	6	116	52
920703	43	10	72	6	93	76
920704	64	4	84	10	43	51
920705	98	2	85	13	64	47
920706	67	3	82	4	98	52
920707	62	3	82	9	67	42
920708	92	6	83	10	62	52
920709	91	8	91	14	92	57
920710	126	2	95	13	91	49
920711	81	4	89	13	126	48
920712	123	8	91	5	81	61
920713	66	5	91	14	123	48
920714	93	3	97	12	66	41
920715	104	5	95	16	93	42
920716	92	7	87	9	104	63
920717	93	7	90	9	92	70
920718	67	7	85	9	93	64
920719	106	3	89	8	67	43
920720	120	2	92	8	106	47
920721	87	6	93	7	120	59
920722	63	10	77	8	87	79
920723	69	8	86	12	63	77
920724	36	10	72	11	69	100
920725	55	10	74	7	36	87
920726	53	9	79	8	55	87
920727	51	10	86	8	53	77
920728	70	4	83	12	51	54
920729	112	0	88	5	70	55
920730	106	4	87	3	112	63
920731	104	5	90	11	106	70

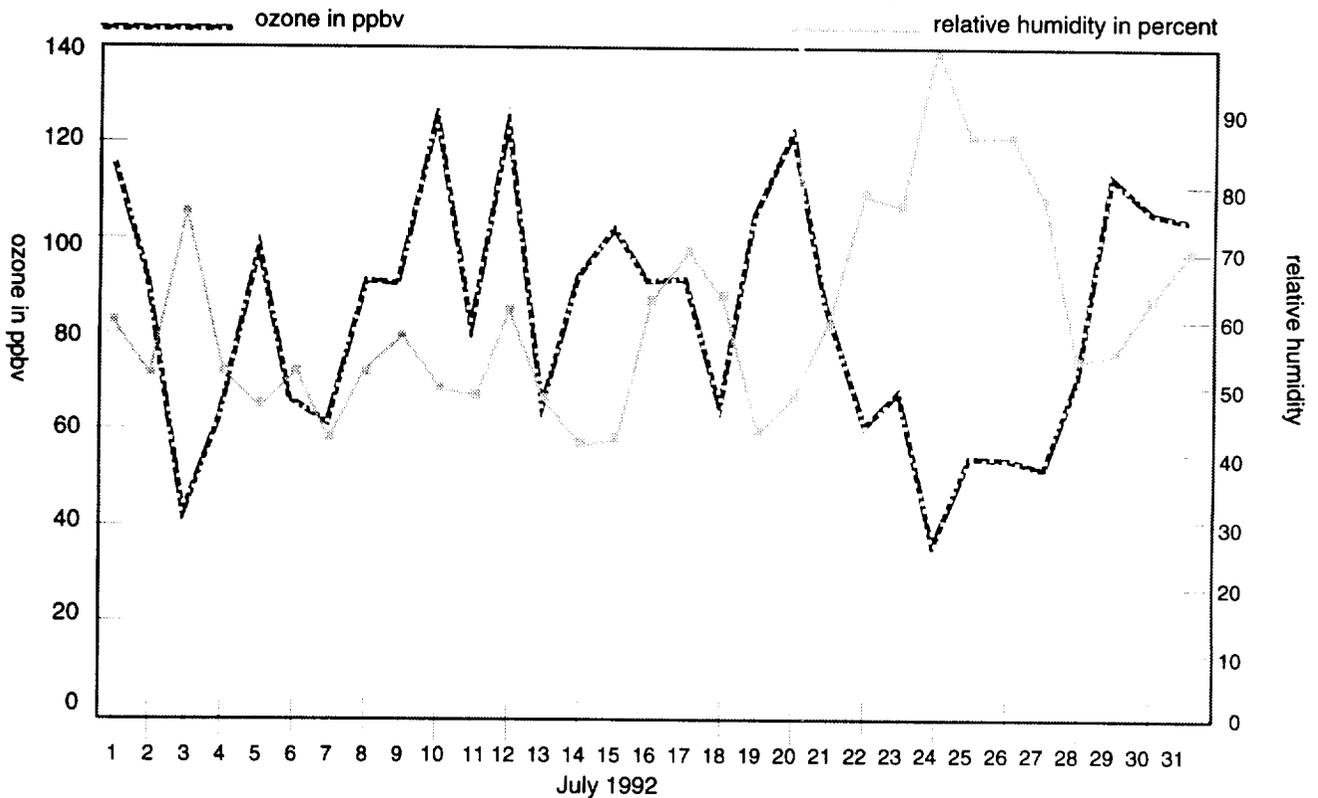
* The National Ambient Air Quality Standard is 120 ppbv, meaning that 120 ppbv is the threshold for problem levels of ozone for a one-hour time period. Now proposed is also a standard for an eight hour average--and that is 85 ppbv.

Project 2 - Sample Comparisons The following graphs are included for teacher reference and should not substitute for students producing their own graphs.

Ozone & Cloud Cover



Ozone and Relative Humidity



Ozone and Maximum Temperature

